Radial versus right internal thoracic artery as a second arterial conduit for coronary surgery: Early and midterm outcomes

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Objective: We sought to compare early and midterm clinical outcomes in patients receiving a right internal thoracic artery or a radial artery as the second arterial conduit for myocardial revascularization.

Methods: Data prospectively collected for all patients who underwent coronary artery bypass surgery between April 1996 and May 2001 and who received both a left internal thoracic artery graft and either a right internal thoracic artery (n = 336) or a radial artery graft (n = 325) were analyzed. Patients in the radial artery group were older, with a greater body mass index, poorer ejection fraction, greater prevalence of diabetes, and higher New York Heart Association class than those in the right internal thoracic artery group.

Results: Odds ratios for perioperative myocardial infarction, atrial fibrillation, postoperative transfusion, and intensive care unit stay all showed a statistically significant benefit in the radial artery group compared with results in the right internal thoracic artery group ($P \leq .05$). Survival estimates at 18 months for patients who received right internal thoracic artery and radial artery grafts were 98.4% and 99.7%, respectively (hazard ratio, 0.25; 95% confidence interval, 0.06-1.10; $P = .07$). Estimates for survival free from any cardiac-related event or death in the right internal thoracic artery and radial artery groups were 92.3% and 97.8%, respectively (hazard ratio, 0.37; 95% confidence interval, 0.16-0.84; $P = .02$). A multivariate Cox regression model showed a stronger protective effect of a radial artery graft (hazard ratio, 0.25; 95% confidence interval, 0.12-0.51; $P < .0001$).

Conclusion: Early and midterm outcomes of myocardial revascularization with 2 arterial grafts are better if the radial artery is used for the second graft rather than the right internal thoracic artery, assuming that the left internal thoracic artery is used for the first arterial graft.

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The benefits of a left internal thoracic artery (LITA) graft to the left anterior descending coronary artery (LAD) have been well documented, particularly with respect to long-term patency survival, cardiac event–free survival, and conduit patency rates, when compared with results with saphenous vein grafts.[1-4] This has lead to the widespread use of arterial coronary revascularization techniques. After the first disappointing experience more than 2 decades ago,[5] Acar and

colleagues[6] stimulated renewed interest in the use of the radial artery (RA) in coronary artery bypass grafting (CABG). Since then, many groups have reported encouraging short-term and midterm clinical and angiographic results with this conduit.[7-10] On the other hand, the use of the right internal thoracic artery (RITA) as a second arterial graft has been shown to decrease the risk of death, reoperation, and percutaneous transluminal coronary angioplasty when compared with a single-LITA strategy.[11-13] Bilateral thoracic artery use is, however, still limited because of the increased operative time, the potentially increased morbidity rate, and the technical complexity of the operation. Moreover, some investigators have reported contradictory results in relation to additional survival benefits.[14,15] At our institution, we started using the RA for coronary revascularization in 1996 as an additional alternative arterial conduit of the RITA for multiple arterial revascularization. The aim of this study was therefore to compare early and midterm (5 years) outcomes in patients receiving an RITA versus those receiving an RA as the second arterial conduit.

Methods

Patient Selection and Data Collection

A standard set of perioperative data are collected prospectively for all patients undergoing CABG at our institution. The data set includes 5 different sections to be filled in consecutively by the anesthetist, surgeon, intensive therapy unit personnel, high dependency unit personnel, and ward nurses. Data are entered into a database (Patient Analysis and Tracking Systems; Dendrite Clinical Systems, London, United Kingdom). This article analyses data for all patients who underwent CABG between April 1, 1996, and May 12, 2001, and who received both an LITA graft and either an RITA or an RA graft. Patients who did not receive an LITA graft or who received additional arterial grafts (eg, RITA and RA grafts) were excluded.

Anesthetic and Surgical Technique

Anesthetic technique, heparin management, and conductance of cardiopulmonary bypass were standardized and have previously been reported.[16] Myocardial protection was achieved by using intermittent anterograde hyperkalemic warm blood cardioplegia.[17] During the period of the study, the unit has adopted the technique of off-pump surgery and now uses this method with increasing frequency; patients having their operation by means of either technique were eligible. The method of exposure and stabilization used to perform the anastomosis in patients who underwent off-pump surgery has been described previously.[18]

The ITA harvesting was carried out by using a diathermy technique (the entire vascular pedicle is taken down en bloc with about 1-2 cm of surrounding tissue on either side). Lateral intercostal branches were divided between ligature clips rather than cauterized. The RA was dissected through a skin incision starting 2 cm distal to the elbow and ending 3 cm proximal to the wrist.[19]

The RA graft was used only in patients with a palpable ulnar pulse and a negative Allen test result. The LITA was used as an in situ graft, generally to revascularize the LAD territory, whereas the RITA or RA was preferentially directed to the circumflex and right coronary artery territories. The choice of using an RA or RITA as the second arterial conduit was entirely at the discretion of the operating surgeon and often based on the patient's preoperative characteristics and coronary anatomy. The RA was generally preferred to the RITA for patients with diabetes, obesity, poor ejection fraction, and respiratory impairment.

Postoperative Management

At the end of the operation, patients were transferred to the intensive therapy unit (ITU) and managed according to the unit protocol.[16]

In-hospital mortality was defined as any death that occurred within 30 days of the operation. Clinical diagnostic criteria for perioperative myocardial infarction (MI) were new Q waves of greater than 0.04 ms or a reduction in R waves of greater than 25% in at least 2 leads. ST-segment changes, inotropic support, pacing requirements, and arrhythmias were recorded and defined as previously reported.[16] Pulmonary complications included chest infection, ventilation failure, reintubation, and tracheostomy. Postoperative blood loss was defined as total chest tube drainage. Neurologic complications included permanent and transient stroke. Renal complications included acute renal failure, as defined by the requirement for hemodialysis, or a postoperative creatinine level of greater than 200 μmol/L. Finally, infective complications included septicemia and sternal and leg wound infections, as defined by positive culture and administration of antibiotic therapy.

We aim to discharge patients undergoing CABG on the fifth postoperative day. The suitability of patients to be discharged home is made by an independent physician according to our unit protocol.[16]

Patient Follow-up

Follow-up was performed during outpatient visits at 6 weeks, 3 months, and 1 year after the operation and then during telephone interview with the patient.

Patients were assessed for survival and cardiac events, which included the need for a further coronary revascularization procedure (reoperation or percutaneous transluminal coronary angioplasty) or coronary angiography, MI, congestive heart failure, arrhythmia, or recurrent angina. Clinical diagnostic criteria for all cardiac events other than recurrence of angina have been previously reported.[16] Recurrence of angina was evaluated clinically and supported by means of exercise electrocardiographic testing. Hospital admissions were examined by obtaining the clinical notes or by means of general practitioner telephone interview to confirm or ascertain diagnosis and treatment.

Sample Size

The analysis included data for all patients who were operated on during the stated period and who received 2 arterial grafts. There were approximately the same number of patients with an RA as with an RITA graft. For dichotomous outcomes, this allocation ratio and the total available sample size of 661 patients meant that the study had 80% power to detect an absolute decrease in risk of about 9% (ie, 25% vs 16%) or an absolute increase in risk of about 10% (ie, 25% vs 35%) in the RA group if the probability of the outcome was 25% in the RITA group. For rarer events (eg, if the

probability of the outcome was 10% in the RITA group), the study had 80% power to detect an absolute decrease in risk of about 6% (ie, 10% vs 4%) or an absolute increase in risk of about 10% (ie, 10% vs 18%). Changes of these magnitudes in the probability of an outcome were considered to be clinically important.

Statistical Analysis

First, several known prognostic variables were compared between the RITA and RA groups. All prognostic variables associated with type of operation (Table 1) were considered to be potential confounding factors. Short-term outcomes for the RITA and RA groups were compared both with and without adjusting for possible confounding by using multiple linear or logistic regression (STATA version 7.0), depending on whether the outcome was a dichotomous or continuous variable. Midterm outcomes were compared between groups by using survival analyses (Cox regression). All analyses calculated robust confidence intervals (CIs), taking account of clustering of patients within surgeon categories. Some outcomes were dichotomized, total length of stay and blood loss were transformed into natural logarithms to normalize the distributions, and postoperative hemoglobin was analyzed in natural units. The number of prognostic variables and outcomes of interest resulted in a large number of statistical comparisons. No correction was made for multiple comparisons, but CIs and exact *P* values are presented throughout. Our interpretation of the findings takes into account the consistency of the findings and their magnitude, as well as their statistical significance.

Results

A total of 4222 patients underwent CABG at our institution between April 1, 1996, and May 12, 2001 (hospital mortality, 1.2%). Of these, 661 patients received 2 arterial grafts, one with the LITA and the other either with the RITA (336 [50.8%]) or the RA (325 [49.2%]). The proportion of operations using the RA increased steadily during the study period (Figure 1).

The RITA graft was used as a pedicle graft in 94% of cases and for the rest as a free graft. The RA was used as a free graft in 78% of cases, and in the remaining cases it was connected end to side to the LITA with a technique described by Tector and colleagues.[20]

The distributions of a wide range of prognostic characteristics in the RITA and RA groups are shown in Table 1. Several of the prognostic characteristics were distributed unevenly ($P < .05$), with the RA group containing, on average, patients at higher risk (ie, older patients, more female patients, higher body mass indexes, more patients with a worse ejection fraction, more diabetic patients, and, on average, higher New York Heart Association class and Parsonnet score). However, the proportion of patients in the RITA group who received grafts to both the LAD and circumflex arteries was lower than that in the RA group. The proportion of patients in the RITA group who underwent on-pump surgery was higher, and, on average, patients in the RITA group had more urgent need for surgical intervention and required more distal anastomoses.

Early Outcomes

The distributions of early mortality and morbidity are described in Table 2, and the unadjusted and adjusted effect sizes comparing the RA and RITA groups are shown in Table 3.

The unadjusted odds ratios for perioperative MI, atrial fibrillation, postoperative transfusion, ITU stay of greater than 1 day, and ITU or high dependency unit stay of greater than 2 days all showed a statistically significant benefit from having an RA rather than an RITA graft ($P \leq .05$).

Adjusting for prognostic variables that were distributed unevenly between groups, including the site of anastomosis of the 2 arterial grafts, did not substantially alter these findings. The odds ratio estimates shifted further from unity, indicating an even larger benefit from an RA compared with an RITA graft, as would be expected given that the RA group included patients who were, on average, at higher risk of adverse outcomes.

Midterm Outcomes

Midterm outcome data for death and cardiac-related events were available for 655 (99%) of 661 members of the study population. The distributions of all deaths and cardiac-related events during follow-up are shown in Table 4. Almost all types of event occurred more often in the RITA group, but this simple comparison does not take account of differences in the duration of follow-up between groups, which arose because operations with the RA tended to have been carried out more recently. The median duration of follow-up was 655 days (1.79 years) for patients who received an RITA graft and 564 days (1.54 years) for patients who received an RA graft.

Survival estimates (ie, for all causes of death) at 18 months, without adjusting for covariates, were 98.4% (95% CI, 96.1%-99.3%) in the RITA group and 99.7% (95% CI, 97.8%-100.0%) in the RA group (hazard ratio for RA graft, 0.25; 95% CI, 0.06-1.10; $P = .07$; Figure 2, *A*). Because there were so few deaths, it was not possible to fit a multivariate Cox regression model to take account of all prognostic variables that differed between groups. However, a Cox model taking account of the main imbalances between groups with respect to prognostic factors (Parsonnet score, sex, diabetes, and the site of the arterial grafts) showed a stronger protective effect of an RA graft against all causes of death (hazard ratio, 0.18; 95% CI, 0.05-0.66; $P = .01$).

Estimates for survival free from any cardiac-related event or death at 18 months, without adjusting for covariates, were 92.3% (95% CI, 88.6%-94.8%) in the RITA group and 97.8% (95% CI, 94.7%-99.1%) in the RA group (hazard ratio for RA graft, 0.37; 95% CI, 0.16-0.84; $P = .02$; Figure 2, *B*). A multivariate Cox regression model taking account of the main imbalances between groups with respect to prognostic factors (age, sex, diabetes, ejection fraction, Parsonnet score, pre-

TABLE 1. Distribution of prognostic variables

Prognostic variable (n_{RITA}/n_{RA}) when there were missing data	RITA (n = 336)		RA (n = 325)		*P* value
	n	%	n	%	
Date of the operation					< .0001
April 1, 1996 to March 31, 1999	191	56.9	123	37.9	
April 1, 1999 to March 31, 2000	102	30.4	97	29.9	
April 1, 2000 to May 12, 2001	43	12.8	105	32.3	
Age at the operation (y)*	55.5 ± 7.8		57.7 ± 8.1		.0003
Body mass index (n = 334/323)*	27.5 ± 3.2		28.2 ± 3.9		.02
Female sex	29	8.6	51	15.7	.005
Risk factors					
Fair or poor ejection fraction (n = 334/324)	46	13.8	85	26.2	< .0001
Previous myocardial infarction (n = 336/324)	127	37.8	137	42.3	.24
Previous stroke (n = 335/324)	9	2.7	18	5.6	.06
Serum creatinine > 120 μmol/dL (n = 332/322)	53	16.0	53	16.5	.86
Respiratory impairment (n = 335/325)	21	6.3	28	8.6	.25
Redo CABG	9	2.7	17	5.2	.09
Diabetes (n = 336/324)	21	6.3	59	18.2	< .0001
Hypercholesterolemia	276	82.1	263	80.9	.69
Hypertension	167	49.1	267	51.4	.67
Canadian classification score					.22
1	27	8.0	33	10.2	
2	125	37.2	97	29.9	
3	105	31.3	115	35.4	
4	79	23.5	80	24.6	
NYHA score					.02
1	98	29.2	87	26.8	
2	167	49.7	136	41.9	
3	64	19.1	87	26.8	
4	7	2.1	15	4.6	
Extent of coronary heart disease (n = 336/324)					.85
Two affected vessels	122	36.3	120	37.0	
Three affected vessels	214	63.7	204	63.0	
Smoking history					.88
Never smoked	75	22.3	74	22.8	
Past smoker	198	58.9	195	60.0	
Current smoker	63	18.8	56	17.2	
Preoperative arrhythmia	6	1.8	6	1.9	.95
Parsonnet score					.001
0-5	292	86.9	243	74.8	
6-10	30	8.9	62	19.1	
11-15	11	3.3	14	4.3	
>15	3	0.9	6	1.9	
Urgent operation	168	50.0	136	41.9	.04
No. of distal anastomoses (n = 336/324)					.02
2	130	38.7	145	44.8	
3	146	43.5	145	44.8	
≥4	60	17.9	34	10.5	
Site of RITA/RA graft (n = 336/324)					< .0001
Right coronary/PD artery	178	53.0	124	38.2	
Circumflex artery	105	31.3	188	57.9	
LAD	53	15.8	13	4.0	
Arterial grafts (LITA and RITA/RA) to both LADs, and circumflex arteries	158	47	201	61.8	.001
On-pump surgery	258	76.8	197	60.6	< .0001

PD, Posterior descending; *NYHA,* New York Heart Association.
*Mean and SD shown for continuously distributed variables.

operative New York Heart Association classification, and site of the arterial grafts) showed a stronger protective effect of an RA graft against all causes of death (hazard ratio, 0.25; 95% CI, 0.12-0.51; $P < .0001$).

Discussion

The increasing interest in the use of the RA as a coronary bypass graft has been based on encouraging early and midterm clinical and angiographic results[6-10] and the well-documented long-term failure of saphenous vein conduits.[1-4] A review of the literature[21] shows that the early average patency rate and perfect patency rate (within 6 months) of the RA is 98% and 90.8%, respectively, and the rate of perioperative morbidity and mortality is well within the usual range for primary coronary operations. Five-year RA perfect patency rates have been recently reported by Acar and colleagues[7] and by Possati and associates[8] to be 85% and 87%, respectively. On the other hand, the excellent results obtained with the LITA have led to the use of both thoracic arteries for myocardial revascularization,[22] and recently, 2 large-scale studies and a systematic review have shown that long-term survival with both thoracic arteries is better than that with a single thoracic artery.[12,13,23] Other studies have reported contradictory results about additional survival benefits with bilateral thoracic arteries for myocardial revascularization.[14,15] These conflicting results, as well as a longer and more technically demanding operation, are the probable reasons for the relative lack of popularity of bilateral thoracic artery harvesting.[24]

The present observational study showed that the use of the RA as a second arterial conduit of choice is associated with several early and midterm clinical advantages compared with the use of the RITA. The RA could be harvested in almost every patient because clinical contraindications (positive Allen test result, need for hemodialysis, history of previous vascular trauma to the upper limbs, and presence of Raynaud or Dupuytren disease) were quite rare. The higher prevalence of diabetes, elderly age, chronic obstructive pulmonary disease, and worse ejection fraction in the RA group reflects our concerns with respect to sternal infection after bilateral ITA grafting, which was therefore reserved for a selected group of younger, nonobese, non–insulin-dependent diabetic patients.

The attractions of the RA compared with the RITA during the operation are obvious. It is a versatile conduit that can be harvested easily and safely, it has handling characteristics superior to those of the RITA, and it reaches comfortably any coronary artery target, features making it more versatile during the operation and rendering the coronary anastomosis easier and faster to perform.

Mortality was similar for the RITA and RA groups, despite a higher prevalence of risk factors in the RA group. Patients receiving an RA had a significantly lower incidence of perioperative MI and atrial fibrillation compared with patients receiving an RITA. Furthermore, postoperative bleeding and red cell transfusion requirements were significantly less in the RA group, and this was associated with a shorter ITU stay. However, there was no difference regarding the incidence of chest reopening for bleeding between the 2 groups, as reported by Lemma and coworkers[25] and by Borger and colleagues.[26] In both these studies, there was a lower incidence of sternal wound complications in the RA group and a reduced hospital stay. Our results did not show a statistically significant difference in the incidence of sternal wound infection between the 2 groups, which might explain the fact that we did not observe a difference in hospital stay.

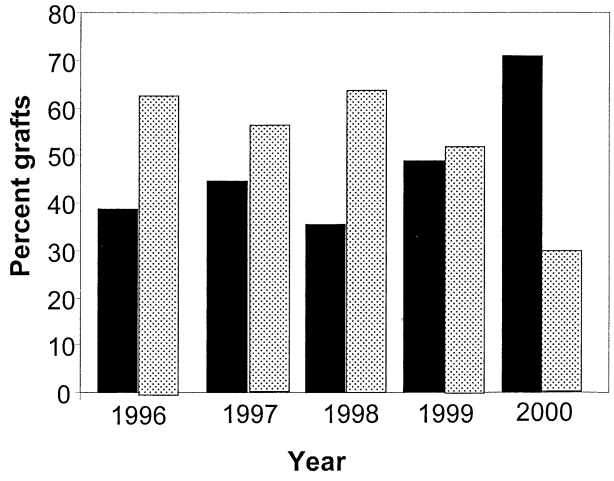

Figure 1. Percentage of RA and RITA grafts by year: *filled squares,* RA; *shaded squares,* RITA. Data for each year are from April 1 to March 31 of the following year, except for the year 2000, which includes data up to May 12, 2001.

Midterm survival free from any cardiac-related events or death showed significant advantages when the RA graft was used for myocardial revascularization compared with when the RITA graft was used. Other reports[7,8] have demonstrated low mortality rates, excellent survival curves, and encouraging 5-year patency rates with the use of the RA. To the best of our knowledge, only one small study[26] has compared the midterm results in patients receiving the RITA or RA as the second arterial graft, and their results showed a nonsignificantly higher survival free from cardiac events in the RA group.

Limitations of the Study

Could our results be explained by bias, confounding, or chance? Chance is unlikely, given the consistent direction of effect size estimates and the strength of the findings for several outcomes.

It might be argued that without blinding of the patients and their caretakers, some of the short-term outcomes could be biased by knowledge of the type of arterial graft. However, we believe that bias from a lack of blinding is unlikely to be an explanation for the results. First, none of the health care staff were aware when collecting-recording the data

TABLE 2. Distributions of outcomes

Outcome (n_{RITA}/n_{RA}) when there were missing data	RITA (n = 336)		RA (n = 325)	
	n	%	n	%
Deaths in the hospital	3	0.9	1	0.3
Perioperative myocardial infarction (n = 336/324)	7	2.1	1	0.3
Inotropes on recovery (n = 335/321)	78	23.3	71	22.1
Postoperative atrial fibrillation (n = 336/324)	32	9.6	13	4.0
Neurologic complication (n = 336/324)	2	0.6	2	0.6
Respiratory complication (n = 336/324)	23	6.9	19	5.9
Ventilated >12 h (n = 336/324)	83	24.8	72	22.3
Renal complication (n = 336/324)	8	2.4	5	1.5
Infective complication (n = 336/324)	5	1.3	7	1.9
Blood loss > 1000 mL (n = 281/270)	138	49.1	125	46.3
ln (blood loss) (n = 281/270)*	6.89 ± 0.55		6.84 ± 0.44	
Postoperative hemoglobin† (g/L) (n = 291/288)*	10.3 ± 1.3		10.3 ± 1.2	
Postoperative transfusion (n = 297/295)*	139	46.8	44	14.9
ITU stay (d)				
0	29	8.6	26	8.0
1	239	71.1	249	76.6
2	37	11.0	26	8.0
3	17	5.1	17	5.2
>4	14	4.2	7	2.2
Combined ITU and high dependency unit stay (d) (n = 334/320)				
1	31	9.3	32	10.0
2	156	46.7	169	52.8
3	71	21.3	68	21.3
4	46	13.8	28	8.8
>5	30	9.0	23	7.2
Total length of stay (d) (n = 330/321)†				
0-7	253	76.7	248	77.3
8-10	47	14.2	47	14.6
11-15	20	6.1	14	4.4
>16	10	3.0	12	3.7
ln (length of stay) (n = 330/321)*‡	1.89 ± 0.33		1.88 ± 0.35	

*Mean and SD shown for continuously distributed variables.
†At 48 hours postoperatively.
‡Excluding length of stay for 4 patients who died in the hospital.

that the comparison between RA and RITA grafts was going to be made. Second, as described above, strict local guidelines are used to make decisions about transfusion because it is unethical to expose a patient to the risks of transfusion unnecessarily. These guidelines were applied carefully throughout the period of the study and would have minimized the opportunity for bias. Third, there are similar local guidelines for use of ITU and high dependency unit beds; these resources are limited, and there are strong pressures to implement the guidelines to maintain the workload of the unit.

Bias could also have arisen from missing data if there was a tendency for data to be missing selectively for the highest risk patients who received an RA graft. It can be seen from Tables 2 and 3 that there were few missing data (<5%) for all prognostic variables and for all outcomes, with the exception of blood loss, transfusion requirement, and postoperative hemoglobin. Data for these variables were not collected from April 1996 to April 1997, which accounts for the majority of missing data. Bias from missing data is therefore unlikely.

Without random allocation, it is not possible to exclude the possibility that the findings arise from confounding. However, we believe that confounding is unlikely to explain the benefits observed in the RA group for several reasons. It is certainly the case that allocation of patients to receive an RITA or RA graft did not happen arbitrarily. However, surgeons have generally preferred to use the RITA as a second arterial graft,[12] with the RA used as second best when it is technically difficult or dangerous for the patient (with respect to postoperative morbidity) to use the RITA. The increase in the use of RA grafts over time is the result of the encouraging reports in the literature and also the increased number of high-risk patients (with poor-moderate ejection fractions, diabetes, higher Parsonnet scores, and more urgent operations) undergoing CABG during the study period. That this was indeed the basis for allocating patients to the RITA or RA groups is supported by the observed

TABLE 3. Effect of RA versus RITA graft on mortality and morbidity outcomes; Unadjusted and adjusted effect sizes

	Unadjusted effect size			Adjusted effect size*		
Outcome	**OR/mean difference**	**95% CI**	***P* value**	**OR/mean difference**	**95% CI**	***P* value**
In-hospital deaths	0.34	0.03 to 3.30	.35	0.06	0.00 to 1.08	.06
Perioperative myocardial infarct	0.15	0.02 to 1.03	.05	0.14	0.02 to 0.93	.04
Inotropes on recovery	0.94	0.63 to 1.38	.74	0.92	0.58 to 1.45	.72
Postoperative atrial fibrillation	0.40	0.25 to 0.62	<.001	0.34	0.21 to 0.54	<.001
Neurologic complication	1.04	0.16 to 6.69	.97	1.43	0.09 to 23.2	.80
Respiratory complication	0.85	0.40 to 1.79	.67	0.89	0.41 to 1.92	.76
Ventilated ≥12 h	0.87	0.58 to 1.31	.50	0.81	0.50 to 1.31	.39
Renal complication	0.64	0.34 to 1.23	.18	0.71	0.35 to 1.43	.34
Infective complication	1.83	0.66 to 5.13	.25	1.25	0.42 to 3.69	.69
Blood loss >1000 mL	0.89	0.64 to 1.25	.51	0.84	0.59 to 1.20	.33
ln (blood loss)†	−0.05†	−0.14 to 0.03	.20	−0.05†	−0.12 to 0.03	.21
Postoperative hemoglobin‡ (g/dL)	−0.07†	−0.24 to 0.11	.42	−0.05†	−0.22 to 0.13	.58
Postoperative transfusion	0.20	0.14 to 0.29	<.001	0.03	0.01 to 0.12	<.001
>1 ITU d	0.72	0.52 to 0.99	.04	0.62	0.38 to 1.00	.05
>2 ITU *or* high dependency unit d	0.75	0.59 to 0.95	.02	0.69	0.49 to 0.99	.04
Length of stay >7 d§	0.97	0.60 to 1.56	.89	0.91	0.57 to 1.47	.71
ln (length of stay)†§	−0.01†	−0.09 to 0.07	.81	−0.02†	−0.11 to 0.07	.63

*Mean difference and 95% CI for the difference shown for continuously distributed variables.
†At 48 hours postoperatively.
‡Excluding length of stay for 4 patients who died in the hospital.
§Adjusted for age at operation, date of operation, sex, body mass index, preoperative Canadian cardiac score, preoperative NYHA classification, ejection fraction, previous Cardiovascular accident/transient ischemic attack, extent of coronary disease, diabetes, Parsonnet score, operative priority, number of distal anastomoses, on/off-pump surgery, and target artery for the RITA/RA graft.

TABLE 4. Distribution of cardiac-related events by RA versus RITA arterial graft*

	RITA (n = 332)‡		RA (n = 324)‡	
Outcome† (n_{RITA}/n_{RA}) when there were missing data	**n**	**%**	**n**	**%**
Death (in-hospital *or* during follow-up)	5	1.5	1	0.3
Myocardial infarct (in-hospital *or* during follow-up)	10	3.0	5	1.5
Repeat coronary artery bypass graft	1	0.3	0	0.0
Repeat percutaneous transluminal coronary angioplasty	2	0.6	3	0.9
Recurrent anginas	31	9.3	10	3.1
Total no. of patients with cardiac-related events	43	11.1	15	4.1

*Median duration of follow-up was 655 days (1.79 years) and 564 days (1.54 years) for the RITA and RA groups, respectively.
†Patients could experience more than one cardiac-related event, and therefore frequencies of separate event categories do not sum to the total number of events.
‡Five patients (4 who had a RITA graft and 1 who had an RA graft) were lost to follow-up.
§The outcome of recurrent angina is defined in the text.

distribution of prognostic factors between groups, with the direction of any imbalance between groups almost always being such that the RA group was at higher risk. Given that patients in the RA group were, on average, at higher risk, confounding could only cause the protective effect of an RA graft to be underestimated. This is demonstrated by the tendency for effect size estimates to become more extreme after adjustment for prognostic variables recorded in the database.

The site of grafting was an exception to this rule, with more patients in the RITA than RA groups having the second arterial graft placed on the right coronary system rather than on the circumflex artery. However, this constraint on grafting of the RITA did not explain the poorer outcomes in the RITA group because the protective effect of an RA graft remained after adjusting for the fact that patients in the RITA graft were more likely to have the second graft placed on the right coronary artery.

Finally, it might be argued that a median duration of follow-up of 18 to 21 months is too short to be clinically

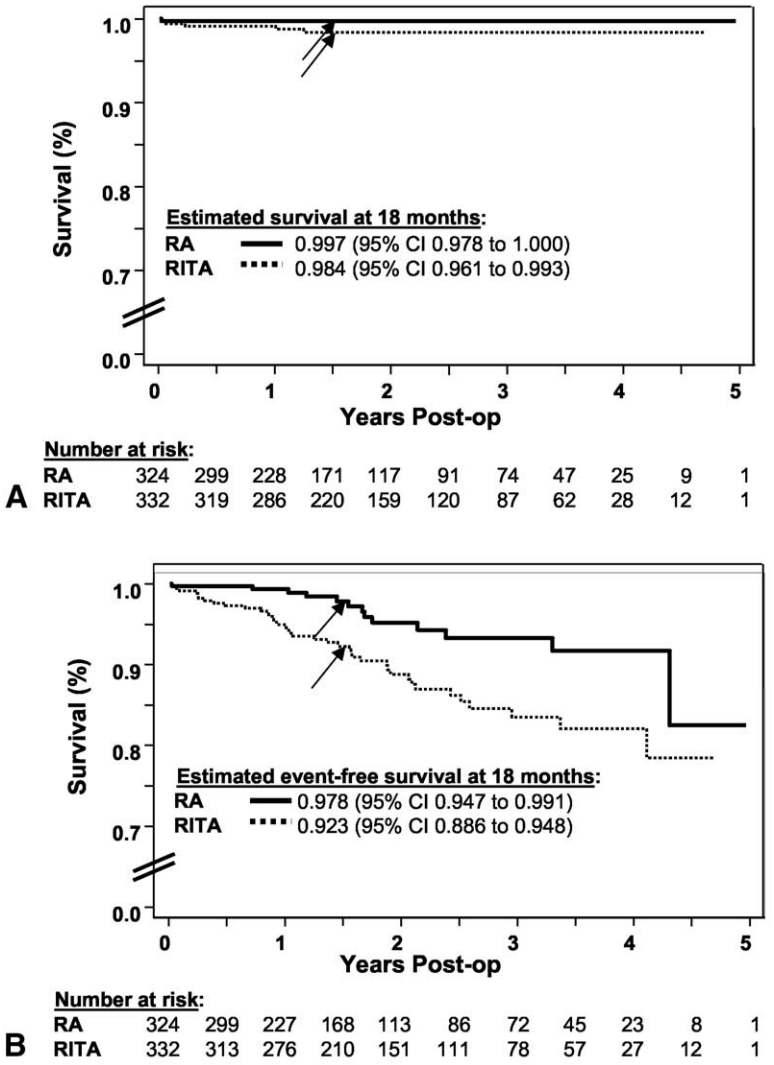

Figure 2. Kaplan-Meier survival estimates for deaths (A) and cardiac events (B) for the RA and RITA groups.

important. Nevertheless, the survival analysis for the combined outcome of all causes of death or cardiac-related events clearly shows a difference between the 2 groups up to 4 and 5 years, and there does not appear to be any tendency for convergence between the 2 survival curves with increasing duration of follow-up. It therefore seems unlikely that these differences will disappear with longer follow-up.

Conclusions

In summary, this study shows that the outcomes of CABG with 2 arterial grafts are better if the RA is used for the second graft rather than the RITA, despite an increased prevalence of risk factors in the RA group and assuming that the LITA is used for the first arterial graft. On the basis of existing reports about RA grafts in the literature and our own experience described in this article, we believe that the RA should be used more often for myocardial revascularization. However, the question of which conduit to use as the second artery of choice can only be answered unequivocally by obtaining long-term results from randomized controlled trials.

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